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THE S I S
for the
D E G R E E
of
B A C H E L O R O F S C I E N C E
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M I N I N G E N G N E E R I N G
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-SUBJECT-

MODERN CYANIDE PRACTICE.

Harvey Edson Smith.

1910.

Approved, *Edward Copeland*
by H. P. Mann.

10942

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1. INTRODUCTION.

It is noticable that about all of the recent improvements in cyanide practise have been along mechanical rather than chemical lines. The use of oxidizers such as air, ozone, sodium peroxide, etc., the use of the salts of lead, and even the addition of a coating of lead to the zinc shavings in the extractor boxes were all recommended when the process was first advocated but sometimes for different reasons. In the early days of the process the addition of hypochlorites, alkaline persulphates, and the use of mercuric cyanide was also investigated but has not proven satisfactory owing to the increases cost. (1.)

If, however, there has been no advance made along the chemical side of the process the reverse is certainly true of the mechanical side. Whereas in the past the attempt of everyone was to crush coarse and make as few fines as possible, now, owing to the improved machinery for the treatment of slime, the tendency is to slime all the ore as this has been found in a majority of cases to give a higher extraction and at less cost than the former practise did.

With the introduction of the Pachusa, or Brown, agitator and the various forms of filters for the handling of slime, many tailings piles, containing low values have ^{been} profitably worked and as new economical features are introduced it is to be expected that the retreatment of old tailings will largely increase.

But probably the greatest advancement recently made in cyanide practise has been the application of the process to silver ores, many of them very low grade. It seems that in general the cyaniding of silver ores may be carried on under practically the same conditions as the cyaniding of gold ores is, except that stronger cyanide solutions and longer treatment are generally necessary.

2. WINNING THE GOLD AND SILVER FROM THE ORE.

A. Preparation of the ore.

a. Mechanical preparation.

There are almost as many ways in which the ore may be crushed before cyaniding as there are possible combinations of the various machines used for that purpose.

In South Africa, breakers followed by stamps and tube mills are generally used. In New Zealand, the fine grinding is done in Wheeler pans, breakers and stamps being used for the coarse crushing. At Goldfield Nevada, the practice is to crush in Gates breakers followed by gravity stamps. (2.) At the El Raza Gold Mine, Santa Barbara Mexico, breakers of the Blake type followed by Huntington mills are used (3.), and at Mercur Utah, three sets of rolls following the breaker knock the shell off the gold. (4) While at the Golden Cycle Mill at Colorado City, the ore is first crushed in Blake breakers, then in ball mills and after roasting the final crushing is done in Chili mills.

The time honored method of crushing gold and silver ores preliminary to cyaniding has been with gravity stamps, and altho

various other schemes, such as crushing by rolls or in special mills have been tried, stamps have all along more than held their own as the most popular method of crushing. About the only place where methods other than gravity stamps have proved efficient have been where it was necessary to roast the ore preliminary to cyaniding.

Before feeding the ore to the stamp batteries it is necessary to subject it to preliminary crushing, either at the rock house at the mine, or at the mill. This preliminary crushing is most usually performed by jaw breakers, either of the Blake or Dodge type, the Blake being almost universally used owing to it being the better balanced machine. However if the capacity of the mill is large, gyratory breakers, commonly of the Gates type, are very often used. The ore is usually crushed in the preliminary breakers to a size varying between one inch and three inches, the average being about one and one half inches. Caldecott in his experiments performed in South Africa found that the best size to which to crush ore to be fed to stamps was one and one quarter inches, and that crushing finer did not increase the capacity of the stamps.

Ever since stamps have been used for crushing their weight has been steadily increasing. Wooden stamps were first used in Germany in the middle ages, then iron-shod wooden stamps in Cornwall, and so on down to the steel stamps in use in South Africa at the present time and which represent the highest developement of the gravity stamp. (6) A few years ago stamps weighing over 1000 lbs, were unheard of, but now, with a very few exceptions, practically all stamps used preliminary to cyaniding, weigh over 1000 lbs. About the maximum weight in the United States and Mexico is 1250 lbs., but in South Africa much heavier stamps are the common practise. The West Rand Consolidated is using stamps weighing 1890 lbs. and the City Deep has recently installed 2000 lb. stamps. These heavier stamps are all designed with long heads, short stems, and low open-fronted mortar boxes without anvil blocks. (7)

The advantages of heavy stamps are:

1. Decreased cost of installlation as fewer stamps are needed to give the same capacity.
2. Reduction in size of mill building owing to the less number of stamps necessary.

3. Less shafting, belting, etc. necessary.

4. Less labor required to tend the stamps. (8)

As regards the size screen to use with the stamps, the practise has recently been radically changed. Formerly it was the custom to have the fine crushing done by the stamps and it has only been recently that the fact^{that} stamps are not economical fine crushers owing to the fact that to crush fine they must do so by abrasion, rather than impact, has been demonstrated by experiment. (9) While formerly it was the custom to use a screen of about thirty mesh, good practise now favors a screen of about eight or ten mesh.

At various times dry crushing has been advocated. The advantages of dry crushing are;

1. No loss due to sliming or float gold.
2. Product can be leached in one step.
3. Easy to crush fine.

While the disadvantages are;

1. Cost of drying furnace.
2. Loss of gold in form of dust.

3. Low stamp duty.

4. Injury to the health of the workmen.

5. Low efficiency of labor, owing to the unfavorable conditions in which the men are forced to work.

6. Injury to machinery by dust.

7. Low depth of ore leached.

8. Great difficulty of concentrating.

Dry crushing has been generally abandoned except where it is necessary to roast the ore previous to the cyanide treatment.

(10)

The stamp duty appears to vary almost directly as the weight of the stamps used, as shown by the following data:

	Weight of stamp.	Tons per 24 hours.
Homestake Mill	900	4
Veta Colorado Mill	1050	6.5
Helipaards Vlei Estate	1550	9.02
West Rand Cons.	1890	17.

All crushing thru about 8 mesh.

One of the noticable features of crushing preparatory to cyaniding, has been the introduction of tube mills as secondary crushers, generally following gravity stamps. The material fed the tube mill is not generally larger than one

eighth of an inch, that being the size that has passed the eight mesh screen, now usually being used on the stamps.

Various style of liners are used, the question as to which is the best still being undecided. Chilled iron plates are used in West Australia, honeycomb blocks and rib liners in New Zealand, silex blocks in South Africa, and rib liners, or the El Oro lining as it is called in Mexico. (11)

Various makes of tube mills are used, the most popular size being twenty two feet by five feet.

The capacity of tube mills depend upon:

1. Diameter of the mill.
2. Velocity of rotation.
3. Weight, size, and number of pebbles.
4. Viscosity of material fed.
5. Character of lining.
6. Physical condition of the ore.
7. Degree of grinding.

And every ore offers a different problem as to the proper adjustments of the conditions so that the greatest capacity

may be obtained. (12)

In a series of experiments performed at El Ore, Mexico, by G. Caetani and E. Burt, they found that the efficiency increases proportionally to the amount of pebbles in mill, increases with coarseness of feed, decreases proportionally to rate of feed, and as regards net profit it varies with the variation of the three factors mentioned. (13)

In Australia the Wheeler pan is generally used for fine grinding and is claimed to be superior to the tube mill for that purpose. In a series of experiments performed at the Ivanhoe Gold Corp., this claim would seem to be substantiated. Two pans were run against one thirteen by three tubemill, and it was found that the two pans did practically the same work as did the tube mill, with a much less first cost. (14)

In tests of the tube mill, performed by H.W. Fox at Colorado Springs it was found that the degree of grinding, the power consumed, and the wear on the pebbles and lining depended upon the pebble load, the tonnage, the thickness of the pulp, and the speed of rotation of the mill. A mill 5ft. by 22ft., belted

direct to a 150 H.P. motor was used. The mill was lined with four inch silex blocks. The total volume was 350 cu.ft. and the maximum pebble load was 33600 lbs. It was found that the greatest efficiency was when 19000 lbs. of pebbles were used.

(15)

When the ore contains much free gold the usual practise is to amalgamate before cyaniding. The pulp is passed over amalgamating plates, which may or may not be silver coated, either directly after stamping or after passing thru the tube mills or other fine grinders. There has recently been a change in the South African practise and secondary amalgamation has been almost universally adopted. After being crushed to eight or ten mesh by stamps, the pulp is passed over plates and after ~~and after~~ tubemilling is again passed over a secondary set of amalgamating plates.

For separating the sands from the slimes, on account of the different methods of treating each product, the Derr classifier has taken a foremost place in American and Mexi-

can practise. By a simple system of reciprocating scrapers, working in an inclined trough this classifier separates the sands up to twohundred mesh, handling about seven hundred tons per twenty four hours, with less than one half horse power. (16)

Where the Dorr classifier is not used the classification or dewatering is generally effected by the use of a V-box or cone classifier, their size depending upon the amount of pulp to be classified. Mr. Caldecott has recently introduced the use of a diaphragm placed near the discharge end of a cone classifier. The spigot is closed until the cone is about two-thirds full of sand, and when opened the discharge gives a much dryer product than does the ordinary cone classifier.

Mr. Caldecott has also recently introduced at the Simmers Deep of South Africa a rotary sand filter table, where all slimes are removed and sands when discharged contain only fifteen percent moisture. (17)

When the ore contains an appreciable amount of the heavy minerals, which break free from the gangue, it is often

concentrated before cyaniding. This concentration is generally effected upon tables of the Wilfley type or upon vanners. The mill of the Desert Power and Milling Co., at Millers Nevada offers a good example of this practise of concentrating before cyaniding. Here, the ore after being crushed by breakers, stamps, and Huntington mills thru thirty mesh is classified and then concentrated upon Wilfley tables, Woodbury concentrators, and vanners, and is then treated by cyanide. (18)

The presence of wood ashes or charcoal in the ore is very injurious to the process and they should always be removed if possible. At the Homestake plant, a very small percentage of ashes or charcoal when inadvertently introduced into the treatment tank was found to lower the extraction about fifteen percent. At the Blaisdell Coscotelian Syndicate at Pachuca, treating old tailings, the pieces of wood and vegetable growth are removed on a cylindrical revolving table, onto which the tailings are fed with water, the wood and vegetable growth being thrown off the table by centrifugal action

(15)

and the ore pulp being discharged at the center of the table.

(19)

b. Chemical preparation.

With some ores it has been found that a better extraction has been obtained by first giving the ore a preliminary roast. At the Golden Cycle mill, Colorado Springs, treating the telluride ores of the Cripple Creek district, the roasting is carried on in eight Edwards furnaces, the ore being cooled after roasting in a water cooled revolving iron cylinder. However they are now planning to cool the ore by building an extension to the hearth of the furnace, open to the air, the ore being conveyed over the hearth by a series of rabbles similar to those used in the furnace. At Mercur Utah, where the ore treated is mainly sulfide, five furnaces are employed. One of the Brown type, one of the Holthoff, and three of the Jackling type which has been found to be the most successful of the three. This furnace is the invention of D.C. Jackling and is one hundred feet long and three feet high, being rabbled by means of an endless chain carrying six beams with twentytwo scrapers each. (20)

When the ore contains much free acid, or soluble salts that would tend to interfere with the extraction of the gold and silver by the cyanide solution, it becomes necessary to add lime to neutralize this acid. The lime may be added at various times during the process, sometimes it is powdered and added to the ore in the storage bins, sometimes added to the water fed the stamps, but more generally it is added in either the percolation or agitation vats. The amount of lime added will depend upon the ore. At Ivanhoe Gold Corp., Kalgoorlie, one lb. of lime per ton is added (21), while the practice at El Ore is to add twelve lbs. per ton. (22)

Lead Acitete is sometimes used in cyaniding. The exact reasoning involved seems to be anything but clear. In one mill at Guanaajuata lead acitete is added to the material in the sand vats and the slime agitation vats before each treatment. In this case it seems that the ore contains soluble sulfides, for instance sodium or potassium sulfide, which act either as reducing agents, using up the helpful oxygen of the solution or actually precipitating the gold and silver from the solution. The lead acitete forms with this soluble sulfide lead sulfide which is insoluble in the solution, and neither a user of oxygen or a precipitant of gold and silver. Another mill, the Golden Cycle of Colo. City, causes the gold solution before entering the zinc boxes to pass over a gunnysack containing a few pounds of lead acitete. The lead salt dissolves slowly and passes on to the zinc boxes. The lead can hardly pass the zinc, ^{so} in this instance, the advantage may be ~~anxxxxxxxxxxx~~ betterment in precipitation due to the formation of a lead-zinc couple. The solution, which is of course to be used again, would at the same time be freed of any soluble sulfides if this be of importance. The addition of lead acitete in some cases certainly seems to help the extraction which is sufficient reason for its use ~~xxxxxx~~ in those cases altho the exact reason be obscure.

B. Bringing the gold and silver into contact with the cyanide solution.

a. Percolation.

The sands are treated by percolation. This is generally in large circular vats made of cast iron or wood. At the Smuggler Union Mill the vats are made of California redwood and are 40 ft. in diameter by 8 ft. high, holding 475 tons. (24) At the Homestake tanks 44 by 9 1/2, having a capacity of 610 tons are used. (25) These represent about the maximum size tanks that are used. In the bottom of the tanks a filter bottom is built, generally consisting of duck over cocoa matting, resting on a lattice work of wood.

There are various ways of filling and discharging these tanks. Where labor is cheap as in Mexico they may be filled and discharged by hand, but where labor is higher and the capacity of the mill will warrant it, various distributing and discharging devices are employed, among which the Butters and Mein Distributer and The Blaisdell Excavator are probably the most popular. At the Golden Cycle mill, the sand tanks are

arranged in two parallel rows, with a belt conveyor running between the rows and a few feet above the tanks. From the conveyor the sands are discharged automatically upon a cross conveyor which delivers the sands to a Butters and Mein distributor. After treatment, the sands are discharged thru a bottom discharge gate by hydraulic water.

The strength of solution and the time of treatment varies with each ore and can only be determined by suitable tests. In general the average strength of solution used would seem to vary between 0.01% and 0.5%, and the time of treatment to be anywhere from twenty four hours to two weeks. The time it will take for a solution to percolate thru a tank, or in other words, the rate of percolation depends upon:

1. Depth of ore, there being a gradually decreasing rate of flow with depth.

2. The pressure, as if the pressure is too great the ore will pack.

3. The temperature, the hotter the water the greater the rate of flow.

(21)

4. The volume and uniformity of the interstices, the rate of flow being faster if the ore is not bedded but is well mixed.

5. The constituents of the ore, sulfides seeming to decrease the rate of flow. (26)

The length of treatment will be governed by the economical limit to which leaching can be continued and will vary with varying conditions.

b. Agitation.

The use of the Brown, or Pachuca, agitator has been a feature of recent cyanide development. In Mexico and the United States, nearly every new plant uses this system of agitation, and in Asia, India, South Africa, and South America it has also found great favor. Australia seems to be the only district that is not making extensive use of the Brown agitator, but this is probably due to the few number of new plants being erected.

(27)

The Brown or Pachuca agitator consists of a cylindrical

tank about forty five feet high and fifteen feet in diameter, having a conical bottom with sides sloping about fifty degrees. In the center of the tank, there is the air lift pipe, having its diameter equal to about one twelvth the diameter of the tank, and into the bottom of this air lift pipe, which extends to within about eighteen inches of the bottom of the tank, a smaller pipe is introduced which carries compressed air. The agitator works on the principle of the air lift. When the air is first introduced, about fifty pounds pressure is necessary to set the pulp in motion, but after the lift is once begun about twenty five pounds is sufficient to keep it in operation. The consumption of air depends upon the proportion of slime to sand, the degree of grinding, and the viscosity of the pulp. In general about one hundred cubic feet of air per minute will be required per one hundred tons agitated and a ten horse power compressor will be necessary. (28)

Various other forms of mechanical agitators are also used, chief among them being the Hendryx, which is similar in

shape to the Brown, the agitation being accomplished by a screw propeller working in the inner tube.

c. Crushing in solution.

There is a constant increase in the application of crushing in solution. The solution used is generally low in cyanide, altho in some cases, as at the mill of the Nevada Goldfield Reduction Co., as strong as 0.01% are used. The advantage of crushing in solution is that a shorter time is then required for the subsequent agitation or percolation. At the mill of the San Rafael y Anexas, it was found that nearly one third of the gold and silver is in solution before the vats are reached. (25)

When the ore is being amalgamated it is necessary to use a weak cyanide solution, as a strong solution will harden the amalgam, the quicksilver coming out in globules and running down the plate. Amalgamation in weak cyanide solution presents no difficulties, except that plates rarely last over six to nine months. With silvered copper plates costing \$2.00

per square foot, this item of renewal is quite a considerable one.

C. Separating the gold and silver bearing solution from the rock residue.

a. Ordinary gravity filtration.

When sands are treated by percolation, the gold and silver bearing solution is drawn off by gravity thru the filter bottom. The general practise is to first leach with strong cyanide solution, then with several weak solutions, and finish with several wash water solutions. The strong and weak cyanide solutions are run to the extractor boxes, and the wash water to the storage tank.

b. Decantation.

Decantation was formerly used quite extensively, especially in South Africa, but it is gradually being superseded by agitation and filtering, the latter method having many advantages over the decantation process as here shown.

Comparison of the processes.

Decantation plant.	Agitation and filtering.
Transference from tank to tank is by centrifugal pumps.	By gravity, and at no cost.
Separation of slime and solution leaves 50% to 60% water in slimes	Only 26% water left.
Imperfect washing by adding water, taking a long time.	Perfect washing by pumping water thru cakes of slime in the press. Time 40 minutes.
Slimes discharged with a flow of water.	Trucks or conveyors.
Average recovery 75%	Average recovery 95%
Cost per ton 49¢	Cost per ton less than 48¢
Average cost of 100 stamp mill \$125 000.00	Average cost of 100 stamp mill \$75 000.00

c. Forced filtration.

There is a constantly increasing number of filters.

The Butters is of the fixed submerged type, the slimes, solutions, and wash waters ^ebeing pumped in and out of the tank by centrifugal pumps. Suction is applied to the filter leaves and the solution drawn thru, while the slime forms a layer on the outside of the canvas. The caked slime is washed with solution and wash water and is then dropped by breaking the vacuum and applying back pressure. The Moore acts on the same principle as the Butters but instead of carrying on all the operations in one tank, the filter leaves are attached to a crane, and after the slime cake is formed the filter frame is carried to other vats for the solution wash, the wash water, and the discharge of the caked slime. (27) The Barry is similar to the Moore and is claimed to have a better plate and no blowing back of the displaced metal carrying solutions. (28)

The Ridgway is of the horizontal circular table type and is continuous in its action. The Oliver which has

been recently installed in the mill of the NorthStar Mines at Grass Valley California is a new type of continuous filter. It consists of a drum, 11 ft. in diameter by 8 ft. wide, revolving on horizontal axes in boxes or tanks. The outer surface of the drum is divided into sections and covered with the filtering medium. The drums are partly submerged in the pulp to be filtered (kept from settling by air agitation) and, as they revolve a vacuum applied to the sections build up a cake of slime on the surface. As the sections leave the pulp, they are dried by vacuum and then a wash water is applied and drawn thru the slime. Just before the section enters the pulp again, air under pressure is admitted to the chamber and the cake is discharged. (29)

The Merrill press, which was first used at the Homestake mill, differs from the other filters in that both the solution of the gold and silver and the extraction of the solution from the waste is accomplished within the filter press itself. (30)

In the Burt filter pressure instead of a vacuum is used. The filter consists of a cylinder mounted in a fixed position at an angle of forty-five degrees, with a large door at its lower end. It carries a series of filter mats, swingingly suspended in its interior, each mat having a connection thru the shell to the main solution pipe fixed to its exterior. The slime is run into the cylinder and then air introduced which forces the solution thru the filter leaves. (31)

The Butters and Moore are the types of filters most generally used altho various forms of the continuous filters are rapidly gaining in popularity. Of the two, the Moore, altho its first cost is greater, is considered by good authorities to be superior to the Butters, as results show that a higher extraction can be obtained with the ^{Moore} ~~Butters~~ than with the Butters. (32)

Alfred James makes a comparison of the various forms of filters, filter presses and the decantation process as follows:

	Recovery of dissolved metal values.	Cost per ton of dry slime.
Ridgway	99.5%	10¢
Dehne (filter press)	99.0%	25¢
Barry	96.0%	12¢
Moore	91.0%	16¢
Rand decantation	85.0%	14¢
Butters	83.0%	16¢

D. Precipitation of the gold and silver from the solution,

Among the various methods that have been tried in precipitating the gold and silver from the cyanide solution are:

1. Precipitation by zinc.
 - a. Shavings
 - b. Dust.
2. Precipitation by charcoal.
3. Precipitation by zinc thread coated with lead.
4. Precipitation by electrolysis.
 - a. Iron anodes and lead cathodes.
 - b. Lead peroxide cathodes and iron anodes.
 - c. Aluminum electrodes.

However today precipitation by zinc either in the form of shavings or dust is the method almost universally employed.

At the Homestake where zinc dust is used the precipitation is carried on in tanks of 300 tons capacity, the contents of the tank being agitated with compressed air, while being sprayed with an emulsion of zinc powder and water. (34)

The precipitation plant of the ElOro M.&M. Co.,

may be taken as an example of good practise when zinc shaving precipitation is employed. Here there are thirty extractor boxes, 16.5 ft. long having five compartments each 4 by 3 by 2 feet, and fourteen boxes, 16.5 feet long having six compartments each 30 by 30 by 24 inches. Each box has a bottom discharge gate opening into a launder to the clean-up tanks. Of the fortyfour boxes, four are used for strong solution (.2% to .3% KCN), four for medium solutions (0.1% KCN), and thirty six for weak solutions (0.03% KCN). The average rate of flow per cubic foot of zinc shavings per twenty four hours is; for strong solution one ton, for medium solution 1.1 tons, and for weak solutions 1.4 tons. At the head of the thirty six weak solution boxes, KCN is added at the rate of thirty six pounds per twenty four hours. (35)

According to W. H. Vengoe, the losses of zinc occurring in the extractor boxes are due to:

1. Unnecessary handling of zinc during the clean-up.
2. Uneven flow of solution, zinc becoming channeled.
3. Poor cutting of zinc threads.

5. Using large amount of zinc with very weak solution.
6. Excessive alkalinity of solution.
7. Precipitation of base metals such as copper, mercury etc.
8. Contact of zinc in boxes with iron. (36)

E. Recovery of the gold and silver from the precipitate.

Probable more care is necessary in the treatment of the precipitate obtained from the extractor boxes, than in any other stage of the process, owing to the fact that the gold and silver values are now so concentrated, that any slight loss will mean a large loss in dollars and cents. After the zinc shorts have been screened out, the precipitate is usually dried in a filter press, altho if the capacity of the mill is small, it may simply be allowed to settle. There are four general methods employed in treating this precipitate:

1. Drying and smelting direct.
2. Drying, roasting and smelting.
3. Acid treatment, drying and smelting.

4. Smelting direct with litharge and cupelling.

Drying and smelting direct is the simplest of the four processes, but should only be employed when no zinc is present in the precipitate. The precipitate is dried in any suitable manner and then mixed in a plumbago crucible with a charge about as follows:

Dry slimes	100 parts
Sodium carbonate	50 "
Borax	35 "
Silica	15 "
Niter	3 "

The resulting bullion is refined and the slag is retreated. (38)

Roasting and smelting as used in certain mills on the Rand is about as follows. The precipitates are not acid treated but are put into whitewashed iron trays and calcined, the operation taking usually about three hours. The calcined precipitates are fluxed in plumbago crucibles with clay liners, the charge being,

Precipitates	100 parts
Manganese dioxide	10 "
Silica	25 "
Borax glass	25 "

The gold buttons obtained are usually of high grade. The slag formed is retreated. (39)

Acid treatment and smelting is the common practise in the United States and Mexico. The slimes are placed in a clean-up vat, provided with a hood to carry off the fumes, and concentrated sulfuric acid is added untill all of the zinc is dissolved, then the vat is filled with hot water, the contents agitated and then drawn off and forced thru a filter press. The precipitate is then treated in crucibles with any suitable flux. The resulting slag after being panned for shot gold is retreated. At Grass Valley California, the precipitate is first treated with sulfuric acid to remove the zinc, then with sulfuric acid and sodium nitrate to remove the copper. The gold is then dissolved in a solution of ten parts sodium chloride, one-hundred parts sulfuric acid, and ten parts potassium permanganate. From this solution the gold is precipitated with ferric sulfate and the precipitate melted with borax and niter. (40)

Smelting direct with litharge and cupelling is known as the Tavener process, and was first introduced at the Bonanza mine, Johannesburg, by P.S. Tavener. The slime after being put thru a filter press is dried on iron trays and then fluxed with litharge, carbon, silica, and iron, in such proportions as to give a button containing 10% gold. After melting the rich slag is retreated and the lead button is cupelled in a cupellation furnace. The resulting gold is refined and the litharge formed in the cupellation is used over again in the process. (41)

F. Treatment of the rock residue.

The disposal of the rock residue is a separate problem for each and every mill, being governed by the location of the mill, the topography, the water supply, whether or not the surrounding country is thickly populated, the cost of power, the cost of labor, etc.

Undoubtedly, where the location of the mill will permit and water is plentiful, the cheapest way of disposing

of the rock residue is to sluice it out and allow it to settle behind dams. Where this method is not possible, the residue may be discharged into cars and these cars either trammed by hand or hauled by an electric motor, or by rope haulage to the tailings piles. Where the surrounding country is well populated, it will generally be necessary to discharge the tailings into ponds and allow the excess water to evaporate, owing to the injurious effect of cyanide on life and vegetation.

3. COSTS.

Owing to the varying conditions prevailing in every country, in every mining district, and indeed in every mill it is impossible to make a comparison of the costs of the various systems of cyaniding, and say that a certain system is the best from a dollars and cents standpoint. However the costs as reported by various mills do give a general idea of what should be expected under like conditions and serve as a basis for a very rough comparison of the processes.

Liberty Bell Mine, Telluride Colorado. (42)
March 1908.

Ore milled	10 548 tons
Solution thru zinc boxes	24 510 "
Precipitate recovered	1 275 lbs.
Bullion from same	16 916 oz.
Metal in precipitate	86%
Bullion fineness	950

COSTS.

Precipitation.

Zinc 4700lbs. @ 8.97¢	\$421.60	
Cutting	85.00	
Labor	81.55	
Power and supplies	<u>26.65</u>	
		\$594.80

Clean-up and filter-pressing.

Labor (12,5 comp. boxes)	43.50
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Refining

Acid treatment		
1050# H ₂ SO ₄ @ 4.6¢	48.30	
Labor	55.30	
Power and repairs	<u>8.45</u>	112.05

Drying and smelting.

Coal 750# @ \$6.00 ton	2.25	
Coke 2500# @ \$17.00 "	21.25	
Flux	32.75	
Crucibles	36.00	
Labor	29.00	
Repairs and sundries	<u>3.05</u>	124.30
		<u>\$874.65</u>

Cost per ton of solution

Precipitation	\$0.0234
Clean-up	0.0018
Refining	<u>0.0096</u>
	\$0.0351

Refining cost per Troy oz. of bullion	\$0.0148
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Desert Power & Mill Co., Millers Nevada. (43)

May 1908.

Ore milled	13.830 tons
Solution thru zinc boxes	81 000 "
Precipitate	27 947 lbs.
Bullion	291 412 oz.
Metal in precipitate	71.5%
Bullion fineness (gold and silver)	972.6

COSTS.

Precipitation

Zinc

Cut at plant 15 060# @ 9.6¢	\$1 529.94	
Shavings 7 764# @ 13.6¢	1 006.32	
Cutting 15 060#	141.00	
Power and supplies	<u>222.45</u>	
		2 899.71

Clean-up and filter-pressing

Labor(17 seven comp.boxes)	519.45
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Refining

Drying and smelting

Coal 7500# @ \$19.44 ton	72.90
Coke 31572# @ \$17.00 "	268.37

Fluxes

Fluospar 158#	8.41
Borax 5454#	418.34
Borax glass 100#	20.50
Soda 2699#	112.01
Crucibles	167.34
Labor	725.55
Repairs and sundries	116.60
Power	<u>18.30</u>

	<u>1 928.32</u>
total	\$5 347.48

Cost per ton of solution

Precipitation	\$0.0358
Clean-up and filtering	n 0.0064
Refining	<u>0.0238</u>
Total	\$0.0660

Refining cost per oz.Troy of bullion

\$0.0066

COST OF TUBE MILLING.

El Oro Mining and Milling Co., El Oro Mex. (44)

Krupp tube mill, 22 feet long by 59 inches in diameter.

Cost per ton.	
Depreciation (three years)	\$0.036
Pebble consumption	0.092
Liner consumption	0.041
Power (steam at \$68.00/H.P.yr.)	0.180
Repairs	0.024
Belting (2 yrs.)	0.003
Labor (3.50 per day)	0.007
Supplies	0.015
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	\$0.398

Montana Tonapah Mining Co., Tonapah Nevada.

Costs of tube milling from Oct. 1st 1907 to June 1st 1908,
during which time 21 511 tons were reground in tube mill.

Cost of power 85 H.P. @ \$8.00	\$5 400.00
Pebbles 70 860# @ \$50.00 per ton	1 770.00
Silex lining	2 216.92
Labor (one half of one mans time)	1 440.00
Maintainance and repairs	
(on mills and Dorr classifiers)	632.00

Cost per ton of ore stamped, 68% of ore being reground.

Power	\$0.170
Pebbles	0.055
Linings	0.069
Labor	0.045
Maintainance and repairs	0.019
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	\$0.358

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